

# **Interim Report: Kenduskeag Water Quality Monitoring Project**

**By**

**Ed Lindsey and the  
Central High School Stream Team**

**Mark Whiting, Maine DEP**

**In cooperation with:**

**Penobscot Indian Nation, Maine Atlantic Salmon Commission, Maine Department of Inland Fisheries and Wildlife, University of Maine Sawyer Environmental Lab, and the NOAA Fisheries Service**

**May 2, 2005**



## **Introduction**

Kenduskeag Stream has an important place in the effort to restore populations of native Atlantic salmon. The Kenduskeag is one of the largest tributaries to the Penobscot River that are located below the first dam on the Penobscot (at Veazie). Kenduskeag Stream has one remaining dam, located at Garland Pond at the headwater source, but is otherwise free flowing. Atlantic salmon have been known to reproduce naturally in the Kenduskeag and there have been sporadic sightings of adult fish from fishermen and US Fish and Wildlife Service biologists from the 1980's and 1990's. For instance in 2003, 50 to 60 adult salmon were observed in Bangor swimming up Kenduskeag Stream and three redds were found later that fall. In 2002, the Maine Atlantic Salmon Commission found 78 wild parr at Bacon Mills during a basin-wide electrofishing survey. The Maine Atlantic Salmon Commission (ASC) has an on-going monitoring program on Kenduskeag Stream. ASC is looking at salmon population indicators such as redd counts and parr densities, and has mapped the available salmon habitat. At least some of the fish in the Kenduskeag are clearly strays from the stocking program in the Penobscot River. The Penobscot River has been stocked almost annually since 1889.

In addition to some natural reproduction and strays, Kenduskeag Stream has been stocked. In 1993, 25,000 salmon fry were stocked in the Kenduskeag as part of the West Enfield Dam FERC relicensing project as mitigation for lost salmon habitat above this dam on the Penobscot. In 2003, as part of a river productivity study, ASC and the US Fish and Wildlife Service experimentally stocked 1,300 fall parr in the river. As part of the same study, another 1,200 parr were stocked in the fall of 2004 and a similar number of fish will be stocked in the fall of 2005. Because two the lower dams on the Penobscot River will be taken out in the near future (Veazie and Great Works) and two more dams will have improved fish passage (Milford and Howland), the Penobscot River and its tributaries will become an even more important part of overall salmon recovery effort in Maine.

## **Project Setting**

With a length of 36 miles and a watershed of approximately 215 square miles, Kenduskeag Stream is one of the most important tributaries on the free flowing part of the Penobscot River (Penobscot County Soil and Water Conservation District website). The mainstem of the Kenduskeag has 12 named tributaries with watersheds that range in size from 3-26 square miles. French Stream, Black Stream, and Crooked Brook are the largest, with 26.3, 26.0 and 19.2 square miles respectively (PC SWCD). The elevation ranges from 10 feet (NGVD) at the confluence with the Penobscot River in Bangor to more than 1,000 feet in the headwaters on Preble Hill in Garland.

By local standards, the Kenduskeag watershed is heavily agricultural. Approximately 40% of the agricultural land in the overall Penobscot River watershed is found in this lower tributary. According to the Penobscot County SWCD, 87% of the watershed (120,000 acres) is forested (primarily with mixed hardwoods) and 16,500 acres is cropland, pasture or grassland. The principal crops are corn and potatoes, with some active dairy and cattle farms. Progress has been made in mitigating agriculture's impact on fish and aquatic habitat. The Penobscot County Soil and Water Conservation District and the Natural Resources Conservation Service have been working with farmers to improve crop and dairy management to minimize impacts to surface water. Over the past 10 years the PCSWCD and local farmers as part of their cost-share have spent over \$4,000,000 on such improvements.

As the river enters the Bangor city limits, the nature of the river changes. The low gradient of the upper river becomes steeper, river runs give way to a series of cascades, the river becomes confined in a rocky gorge, and the rural landscape changes to an urban one. The greater Bangor area has a population of about 80,000 people. An additional 23,000 live the Kenduskeag Stream watershed. Bangor International Airport and the Maine Air National Guard share the large airport facility located in a tributary drainage (Birch Stream). As the Greater Bangor area grows and the Kenduskeag watershed accommodates more new housing construction, protecting this nursery for sea-run fish will become increasingly important.

## **Project History**

In the fall of 2003, Ed Lindsey, a teacher at Central High School in Corinth wanted to

have his chemistry class engaged in a community-oriented project. Because Kenduskeag Stream is located near the school, and because of the current publicity around salmon restoration in Maine, the class wanted to generate data that could be used by state and federal environmental agencies and would benefit salmon recovery. The class first got a “What Kids Can Do” grant from the Bill Gates Foundation for innovative teaching programs and to bring technology into the classroom. The Maine Department of Environmental Protection (DEP) provided some equipment, training and technical help as part of the Maine Stream Team Program. In the spring of 2004, Central High School got an additional grant from the West Enfield Fund (WEF), a fund that was established for salmon mitigation projects due to the FERC relicensing of the West Enfield dam. The WEF money was dedicated primarily to water chemistry analysis. The Sawyer Environmental Lab at the University of Maine offered the school a reduced rate for their laboratory services and Professor Stephen Norton offered additional technical help. The Penobscot Indian Nation (PIN), US Department of Commerce NOAA Fisheries Service and the Maine Department of Inland Fisheries and Wildlife (DIFW) helped plan the project. PIN and DIFW loaned the school temperature loggers. NOAA Fisheries Service offered to loan some equipment and help with GIS technology. In the fall of 2004, the high school got an additional grant from the National Fisheries and Wildlife Foundation (NFWF) Maine Atlantic Salmon Conservation Fund for additional lab chemistry, a laptop computer, and summer salary.

This report is the result of the first year of this study and of this collaboration. Additional field and lab work is planned for 2005. A final report will be written after the end of the 2005 field season. Copies of this report, and the final report when it is finished, will be available from Mark Whiting at the DEP Bangor Regional Office or from Ed Lindsey at Central High School.

## **Methods**

In 2004, students at Central High School began a study of the 5 tributaries of the upper portion of the watershed. Working as a volunteer “stream team” the students were able to obtain leave from their other classes to do field work. They collected field data and took water samples for laboratory analysis at 5 sampling locations on 6 sampling dates from April to November 2004. All field measurements, instrument calibrations, and water bottle collections were performed according to the *Water Quality Monitoring Protocol Manual for Maine Salmon Rivers* (see SHARE website). Sample sites were at the terminus of each tributary, before the confluence with the mainstem (see Figure 1). Sampling at these locations isolated the influence of each basin on water chemistry. Crooked Brook, Kenduskeag Stream, Allen Stream, and French Stream are all third order streams at the road crossings at our sample sites. Pierre Paul Brook is a second order stream.

Field measurements taken at each sampling date appear in the chart below.

Measurement	Equipment
pH	Oakton pH Tester II
Temperature	Vee Gee brand stick thermometer
Turbidity	120cm "turbidity tube"
Dissolved oxygen	YSI DO meter, and LaMotte DO Winkler titration kit
Color	Hach color-wheel kit

Automated temperature loggers were deployed at each sample site. The sites were coordinated with the Atlantic Salmon Commission so as to avoid a duplication of effort. Three varieties of ONSET brand loggers were used. They were calibrated before deployment. Calibration, deployment, and data analysis followed protocols established by the Atlantic Salmon Commission (ASC) (also found in the SHARE manual cited above). Our temperature logger for Kenduskeag Stream was deployed at the outlet of Garland Pond. For comparison, the results from the ASC logger at the Fernald Road crossing (also known as the Bacon Mills Road and located about 4 miles downstream of the pond) are also presented in this report.

Water samples were sent to the Sawyer Environmental Chemistry Lab at the University of Maine (Orono) for analysis of calcium ( $\text{Ca}^{2+}$ ), magnesium ( $\text{Mg}^{2+}$ ), potassium ( $\text{K}^{+}$ ), sodium ( $\text{Na}^{+}$ ), chloride ( $\text{Cl}^{-}$ ), nitrate ( $\text{NO}_3^{-}$ ), sulfate ( $\text{SO}_4^{2-}$ ), dissolved organic carbon (DOC), closed cell pH,

alkalinity or “acid neutralizing capacity” (ANC), total phosphorus (TP), and aluminum species (including “exchangeable aluminum” which is known to be toxic to fish). Samples were taken from all streams on three dates (in July, August and November) for Chlorophyll a analysis. Total suspended solids (TSS) samples were taken after storms when the river appeared to be cloudy. “Closed cell pH” is a lab analysis of pH where the sample was collected and enclosed in a syringe to prevent the loss of carbon dioxide. Total suspended solids are the weight of suspended sediments found in stream water. It is also an indirect measurement of the cloudiness or turbidity of the sample.

Biological Oxygen Demand (BOD) samples were collected 5 times over the season and analyzed at the Penobscot Indian Nation Water Lab. Students did one stream discharge measurement for each stream using the “apple and stop watch” method. This was done during the summer low flow period. Stream staff gauges were installed at each of the sample sites. Staff gauges were installed in the fall, so there are no stream stage readings from earlier in the year. Citizen volunteers read the staff gauges as opportunity permitted.

Precipitation was monitored by citizens with rain gauges. One gauge was in the Upper Kenduskeag Stream basin and the other was in the French Stream basin. Like the stream staff gauges, the rain gauges were established late in the year. For 2004, we used on-line rain gauge data from a NOAA website. A USGS automated stream gauge on the Sebasticook River was used as an indicator of local stream response to storm events. Although geographically closer to the Kenduskeag, the gauge on the Penobscot River at Eddington was not used because of the much larger drainage area this gauge responds to, and because flows on the Penobscot River can be influenced by the manipulation of existing hydroelectric dams.

Bacteria samples were collected on two sample dates (one high flow and one low flow) and were tested for *Escherichia coli* (*E. coli*) bacteria using IDEXX Coli-ert growth media and sample trays. Samples were incubated for 24 hours and read under an UV light. The samples were processed by DEP at the Bangor Regional Office. Bacteria are used as indicators of polluted runoff and of potential problems for human health.

Benthic macroinvertebrate assemblages were collected using rock bag artificial substrates. Two rock bags were deployed at each sampling site in August and were collected and analyzed for macroinvertebrates in October. All of the sample sites are riffle habitats with mixed gravel and cobble substrates. The rock bags were allowed to be colonized by invertebrates and then were recovered in buckets. Due to the time constraints of a single class period, only one bag per sample site was processed for invertebrates. The invertebrates (mostly aquatic insects) were sorted and identified to Order level. The identification and classification of bugs into pollution tolerance groups followed EPA's suggested protocols for volunteer stream teams (EPA, 1997).

## **Results and Discussion**

### **A. Stream Hydrology**

Based on the Sebasticook River stream gauge at Pittsfield (Figure 2) and rainfall recorded in Bangor (Figure 3), the spring of 2004 was dry and the Sebasticook was below the 74-year average flow for the site. While there were significant rain events in April, May and early June, lower than average stream flows dominated through early-August. In contrast, mid-August through September were very wet and flows were above average. The remnants of Hurricane Bonnie crossed Maine on August 13. Other unnamed tropical storms followed into the fall.

Stream discharges in Kenduskeag Stream were measured by students on August 25, 2004. The results are presented in Table 1. These discharges represent a summer "low flow" condition that ranged from 30.58 cfs in French Stream to 10.28 cfs for Pierre Paul Brook. French Stream is probably really the "mainstem" of the river since it is the longest river section and has the most flow. It is not known why the name "Kenduskeag" follows the smaller river segment.

Since we have no actual discharge data for most sample dates, and because discharge is needed to understand transport issues relative to stream chemistry, we calculated "relative flows" based on a nearby stream gauge. Here relative stream flows are taken from the Sebasticook River for a given sample date. The lowest flow on a given sample date was then



used as a denominator to divide all the other flows for the other 5 dates. The resulting numbers ranged from 1 (the lowest flow) to 10 (the highest). These numbers are used as a rough estimate of the amount of discharge on a given sample date and are used for some analyses given below. This analysis acknowledges some problems, like the difference in watershed size for the Kenduskeag (215 square miles total) and for the Sebasticook (572 square miles above the gauge site), and different slopes, and shape for the five different study watersheds. So the relative flows are not to be taken too literally. But we used them as a tool to evaluate the effects of stream discharge on our chemistry data.

## B. General Stream Chemistry

Alkalinity, pH, nutrient levels, turbidity and total suspended solids levels (TSS) are all within ranges that are known to be healthy or are easily tolerated by Atlantic salmon (see Table 2 for lab results, see Danie et al, 1984 on Atlantic salmon requirements). Most other sea-run fish species under consideration for restoration in the Penobscot River Basin would also be likely to thrive in these conditions. Closed cell pH varied from a low of 7.15 observed in Pierre Paul Brook in May to a maximum of 7.99 in French Stream in July. This is a neutral to slightly alkaline range. Kenduskeag Stream had the lowest seasonal variation in pH and Pierre Paul Brook had the greatest (Figure 4). However, there was very little variation in average pH, which ranged from 7.49 for Pierre Paul Brook to 7.66 for Allen Stream. Acid rain occurs in Maine and is sometimes a concern for fishery restoration efforts. Two precipitation chemistry monitoring sites which bracket our sample locations had an average pH of 4.5 measured at Bridgton, Maine and 4.6 at Acadia National Park (National Atmospheric Deposition Program, NADP website) for all wet deposition in 2004. However, all of our study sites appear to maintain pH values above 7.0 even during high flow periods. Thus the episodic acidification and aluminum toxicity observed in the downeast salmon rivers (Whiting, 2003) are of less concern in the Kenduskeag watershed.

Allen Brook and French Stream were the best buffered (i.e., have the most alkalinity or “Acid Neutralizing Capacity” Figure 5) while Pierre Paul Brook was the most dilute. The alkalinity ranged from a low of 26 mg/L (527 ueq/L) in Pierre Paul Brook in April to a maximum of 122 mg/L (2434 ueq/L) in Allen Brook in October. In contrast, the alkalinity of the downeast salmon

rivers vary between 3 and 12 mg/L for baseflow samples and 1 to 5 mg/L for storm flows (Whiting, 2003 and unpublished data). In central Maine, the Sheepscot River ranges from 5.5 to 46 mg/L for baseflow and from 4 to 18 mg/L for storm flows (Whiting 2003). According to the Maine Volunteer Lake Monitoring Program (VLMP 2003) only 3% of Maine lakes have alkalinity greater than 40 mg/L. Unfortunately, at present there is no state-wide database for Maine rivers and streams. But given the state-wide lake data, this puts Kenduskeag Stream and its tributaries among the best buffered surface waters in the state.

Calcium is the dominant cation found in these streams, followed by sodium, magnesium and potassium respectively. Calcium ranged from a low of 9.5 mg/L in Pierre Paul Brook in April to a maximum of 37.3 mg/L in Allen Brook in October (Figure 6). The optimum values for growing young salmonids in a hatchery are 10-30 mg/L (Russell Danner, Dept. Inland Fisheries and Wildlife pathologist, personal communication). This is approximately the same range that is found in the Kenduskeag and its upper tributaries. Calcium also competes with ionic aluminum for gill membrane ion transport sites and thereby helps to mitigate aluminum toxicity. The high calcium levels and the strong buffering capacity noted above strengthen the indication that acidity issues will not be very important in this watershed. Calcium and alkalinity are controlled by the soils and geology of the area. Regions with high calcium and alkalinity tend to have marine derived sediments that are a source of carbonate. Calcium is also added to agricultural soils as lime to maintain soil fertility and moderate pH.

Dissolved Organic Carbon (DOC) ranged from a low of 3.4 mg/L in Kenduskeag Stream in July to a high of 21.3 mg/L in Pierre Paul Brook in August (Figure 7); putting these bodies of water near the mean (5.7 mg/L) for the state (PEARL website). DOC comes from the decomposition of plants and animals. Some of the DOC present in surface water is colored (especially humic materials) and contributes to water color, something we also measured (Table 3). The water color ranged from 5 to 74 standard platinum units (SPU). The lowest values were in the spring during the snow melt period (range 5-8 SPU). Nation wide, water that is greater than 25 SPU is considered to be "colored." Since the average water color in Maine lakes is 28 SPU (PEARL website), many Maine water bodies fall into this category. These colored materials are a source of natural acidity and they are important ligands (or chemical binders) for heavy metals and phosphorus. Mercury, arsenic and aluminum are often bound

with humic matter and can be relatively non-toxic in this form. However, changes in pH and biological activity can cause conversion back into toxic forms. Moderate pH, such as that found in our stream samples, helps keep toxic metals in the organically bound and relatively safe forms. The relationship between the lab DOC and the field water color measurement is given in (Figure 8).

Bicarbonate is the dominant anion, followed by chloride, sulfate, and nitrate. In our part of the United States, almost all of our chloride comes from the atmosphere from marine aerosols or from road salt, and very little comes from local bedrock or soils (Mason et al, 1999). Due to the location of Kenduskeag Stream in interior Maine (more than 40 miles (60 km) from the coast), road salt is a much more important source than marine aerosols. Sulfate comes both from atmospheric inputs ("acid rain") and from the bedrock geology. In Maine, about 70 ueq/L of sulfate in surface water is attributable to atmospheric wet and dry fallout (Stephen Norton, University of Maine, personal communication).

Nitrate is generally the most common form of inorganic nitrogen in surface waters. Nitrate ranged from a low of 0 in Kenduskeag Stream in May to a high of 2.7 mg/L (43 ueq/L) in Allen Stream in April (Figure 9). The average for all sites over all dates is 0.9 mg/L (14.2 ueq/L). Atmospheric inputs for nitrate in Maine are 1.2 mg/L at Bridgton and 1.7 mg/L at Acadia in rainfall (NADP website). While forest soils tend to retain and recycle nutrients and export very little nitrate in surface water, agricultural soils are disturbed. Farm soils use huge amounts of nutrients while crops are growing, but can also be sources of nutrients to surface water. This can be especially true when fields are fallow since there is no uptake by plants. Forest soils account for 120,000 acres and 87% of the land area within the Kenduskeag watershed while crops and pasture account for 16,500 acres or 12% (PCSWCD, 1988). Including atmospheric inputs, the normal background concentrations for northern New England streams are 0.15 to 0.30 mg/L total nitrogen (TN) in headwater streams and 0.075 to 0.15 mg/L TN in rivers (Smith et al, 2003). Approximately the same ranges are reported by Olson and Cowing (1990-1991) for nitrate + nitrite for the major river drainages in Maine. However in the same report, the range for the Penobscot River at Bangor was much smaller, 0.10 to 0.18 mg/L. Values exceeding 1.0 mg/L can be polluted (Murdock et al, 1999). We did not measure nitrite or TN. Still, assuming

that nitrate is the dominant form of nitrogen, the concentrations in the Kenduskeag tributaries are almost ten times greater than probable background values.

Runoff from rain events can be an important transport mechanism for nutrients and pollutants. In our samples, nitrate concentrations have a seasonal pattern in abundance with spring and fall maxima (Figure 10). However, nitrate was not correlated with stream flow. Since we have no flow data for most sample dates, “relative stream flows” are taken from the Sebasticook River for a given sample date. The only apparent relationship for nitrate is in the Kenduskeag, and it is an inverse relationship with flow (Table 4 and Figure 11). Since nitrate is water soluble, and since it is more related to baseflow conditions than high flows, nitrate may be entering these streams primarily with groundwater.

Phosphorus is the other inorganic nutrient that is typically a concern in the enrichment of surface waters. Phosphorus is especially important in regulating the trophic state of lakes. We found that total phosphorus (TP) ranged from a low of 8.2 ug/L in Kenduskeag Stream in November to a high value of 26 ug/L in French Stream in October (Figure 12). Mesotrophic conditions have been observed in Maine lakes at a TP range of 10 – 30 ug/L (VLMP, 2003). Phosphorus is less important in streams since streams do not retain and recycle nutrients the same way lakes do. The median TP concentration predicted as a background level for New England is about 13 ug/L with a range of 10 - 17 ug/L (Smith et al, 2003). Also, the average TP for lakes in Maine is in the middle of this range at 14 ug/L (VLMP, 2003). However, agricultural areas could be very different since phosphorus is known to accumulate in farm soils. In a model that compares pre-industrial soils with modern agricultural soils, a 75% increase in TP storage is suggested for typical agricultural areas worldwide (Bennett et al, 2001). This can lead to enrichment of surface runoff and eutrophication of surface waters. If the expected mean for our area is 14 ug/L and the expected range is 10-17 ug/L, then 9 of our samples out of 30, or 30%, might represent enrichment above a background level.

Phosphorus also appears to have a seasonal pattern with minima in April and October - November (Figure 13) and with high values in May, July, August and (for Allen Stream) in October. Pierre Paul Brook generally had the highest TP (and had the highest average of 19 ug/L), followed by French Stream (with an average of 16.9 ug/L). Pierre Paul is the most

naturally acidic, boggy, and the most highly colored of the streams in our sample set. Pierre Paul is also less agricultural and less developed than the other tributaries. Apparently the natural humic material in this drainage is helping to mobilize phosphorus from soils. Otherwise, phosphorus is often bound tightly to particulate material and might not reach surface water except as suspended sediments in storm runoff. The relationship between TP and flow is poor, except in Kenduskeag mainstem where the relationship is only fair (Table 4 and Figure 14). We experienced our best flows in April and May (relative flows of 5 and 10 respectively) and these generally coincided respectively with both the lowest and highest values of TP. A study by the Penobscot County Soil and Water Conservation District (PCSWCD et al, 1988) reported a seasonal pattern in TP abundance in the mainstem, with highest values in the spring and fall. Our data suggests that in 2004 mechanisms other than flow govern TP in the upper river.

We have TSS data for all sites but only for three sample dates. All of these dates represent relatively high flow periods with two in the spring (April and May) and one in the fall (November). Some of our samples had moderately high TSS values (range 0-55 mg/L) but the high values did not coincide with the highest flows. The highest flows were in the spring, while the highest TSS values occurred in the fall. A simple scatter plot (Figure 15) suggests an inverse relationship with flow. Our turbidity tube field measurements (Table 3) all exceeded 120 cm (i.e., the secchi target was visible even when the tube was completely full of stream water) and demonstrate very good water clarity in spite of some sediment transport. Sometimes large particles (sand) will contribute to high TSS values while not degrading water clarity like fine sediments would. The lack of a relationship with flow is unexpected. It is possible that seasonal factors like agricultural activities are more important than flow *per se*. With respect to phosphorus transport mechanisms, there is essentially no relationship between TSS and TP (Figure 16). It may be that phosphorus is traveling in the Kenduskeag and its tributaries primarily in a soluble organic form and to a lesser extent with fine particles.

Chlorophyll-a is also sometimes used as an indicator of trophic state. In our samples, chlorophyll ranged from below detection limits to 3.4 ug/L for July and August and then ranged from 11.0 to 22.9 ug/L in November. Relative to other surface waters in Maine, this puts the Kenduskeag tributaries in the low to moderate range for most of the summer but in the high range for the highest samples (VLMP, 2003). VLMP considers 1.5 – 7 ug/L to be indicators of

moderate trophic state in Maine lakes and values above 7 are highly productive. DEP uses 8 ug/L as a threshold for rivers (Paul Mitnik, personal communication). Fall and winter are a period of die back for most plants, including algae. It is possible that the November chlorophyll values are elevated by plant senescence and by entrainment in the water column this late in the year.

Our field measurements are summarized in Table 3. Two different methods were used to measure dissolved oxygen, a Yellow Springs Instruments (YSI) Model 55 electronic meter and a LaMotte Winkler titration kit. The resolution of the Winkler kit is limited by the minimum drop size that can be delivered by the titration syringe (about 0.2 mg/L oxygen). Either method should be accurate and provide the same result within the resolution tolerances of the equipment. Figure 17 is a comparison of stream DO measurements using the two methods. The Winkler titration was consistently lower by an average of 0.5 mg/L. This could be due to expired reagents. The YSI meter has a self-diagnostic procedure that should identify battery problems or other sources of error. We have not been getting error messages with the YSI meter. We have recently learned to read the lot numbers on LaMotte reagents and will replace all chemicals before they expire. For the moment, we are assuming the YSI meter data is more reliable

When applicable, field and lab data was compared to state water quality classification standards. Kenduskeag Stream is classed as Class B except for the reach below the Griffin Road Bridge (also known as the Bull's Eye Bridge) just inside Bangor city limits. Below the Griffin Road, the Kenduskeag is classified as Class C. According to the state Class B waters are supposed to support all "designated uses" such as fishing, recreation, drinking water after sufficient treatment, industrial process water, hydroelectric power, navigation and habitat for fish and other aquatic life. Specific numerical standards are set for dissolved oxygen (i.e., DO "shall not be less than 7 parts per million or 75% saturation, whichever is higher"). Special higher DO requirements apply in the winter in order to support over-wintering fish, eggs and fry. None of our samples sites occur in the Class C waters.

In all our samples, dissolved oxygen measurements were all above 7 mg/L and above 75% saturation. These are important thresholds for maintaining coldwater fisheries like salmon and

for maintaining diverse insect assemblages. Similarly, the 5-day biological oxygen demand (BOD) incubations ranged from a low of 0.27 to a high of 2.65 mg/L (Table 5). Unpolluted waters should have a 5-day BOD less than 5 mg/L (Murdock et al, 1999). All of our samples indicate a relatively low level of BOD and very good oxygen saturation, even in the hottest part of the summer.

### C. Biological Indicators

Bacteria samples were taken during one high flow event (5/25/04) and once during summer low flow (7/22/04). The bacteria levels ranged from a low of 102.2 to a high of 1119.9 colonies per 100 ml in May and from a low of 31.8 to a high of 127.4 colonies per 100 ml in July (Table 6). Single values greater than 235 or geometric means greater than 126 colonies are enough to close a public beach. Three samples exceeded the single sample threshold in May (Crooked Brook, Allen Stream, and French Stream). Only two samples (the July samples taken from Allen Stream and Pierre Paul Brook) appear to be near “unpolluted” background levels. All other samples might be thought of as bacteria “enriched.”

The results of our macroinvertebrate collections are given in Table 7. Given the small collection (each bag is only about 0.2 square meter and we had time to look only at one bag per sample site) the species diversity and number of insects are very good. The “EPT taxa” (mayflies, stoneflies and caddisflies) are considered to be indicators of good water quality. The EPT taxa, especially the mayflies, are well represented in our collections. In 2001, the Maine DEP Benthic Macroinvertebrate Monitoring Program evaluated four of our sites (Allen, French, and Kenduskeag Streams and Crooked Brook). All are rated as Class B water, but attained Class A status on the basis of the macroinvertebrates present (DEP, 2001)

### D. Water Temperature Evaluations

One of the best ways to evaluate the effect of water temperature on the survival of sensitive species is to use automated temperature loggers at representative sites. Crooked Brook (Figure 18) is an example of the type of data temperature loggers capture. Over the course of each day, the water warms in response to solar radiation and warming air temperature, reaching

a maximum between 16:00 and 18:00 hours. Then as the sun sets, excess heat is radiated back into the atmosphere and the daily minimum temperature often occurs between 06:00 and 07:00 hours the next morning. This diurnal pattern persists from late spring through summer and early fall, except that clouds and passing cold fronts can cause an interruption in the expected pattern.

Note at the upper right of Figure 18 there is a box that provides the time date and temperature for a given query (the vertical line). For this example, the warmest day of the year for Crooked Brook was on July 22 at 15:00 hours when the temperature was 28.21° C (82.79° F). Based on laboratory incubations, the “incipient lethal” temperature for Atlantic salmon is 27° C (Garside, 1973). Salmon will die when exposed to 7 consecutive days at this temperature. Typically, parr that are exposed to near-lethal temperatures will leave the site and seek thermal refugia such as springs and seeps. The record for this day shows at least four hours above 27° C, which is not lethal for salmon. Temperatures above 30° C are an “imminently lethal” condition where death occurs in a matter of a few hours (Garside, 1973). The horizontal line in Figure 18 is set at 24° C, a third important threshold for salmon. The growth of Atlantic salmon parr generally ceases when water temperatures exceed 24° C (Forseth et al, 2001). If these conditions persist, the fish loose weight and could die. These experimental results match the EPA Ambient Water Quality Criteria, which uses an Upper Incipient Lethal Level (UILL) of 24°C for Atlantic salmon. The UILL for a species is thought to be the environmental conditions where growth is zero. These three thresholds (24, 27 and 30° C) are useful for assessing daily temperature maxima and the suitability of a site to produce juvenile salmon based on thermal characteristics.

A temperature logger record for the Kenduskeag near the outlet of Garland Pond is presented in Figure 19. In this case, there are 41 days in which the daily maximum temperature exceeds 24° C and 11 of these days are consecutive. Juvenile Atlantic salmon at this location would be severely heat stressed during these periods and could loose weight and body condition. Salmon attempting to reside in this location would probably have to seek thermal refuge during these warmest periods.



A summary of the temperature data for all of our sample sites and one of the Atlantic Salmon Commission's sites on Kenduskeag Stream is presented in Figure 20. The warmest water temperatures of the sampling season occurred on August 3 for most of the sites. Crooked Brook approaches lethal limits by day; however it also cools off at night to provide some relief for the fish. Elliott (1991) reports that salmon parr may stop feeding and their normal behavior is disrupted when water temperatures exceed 22.5° C. This can be an important threshold for evaluating daily temperature minima since fish presumably resume feeding below this value. Salmon parr may be able to begin recovery from thermal stress if they can resume feeding and other normal behavior. The sample site on Kenduskeag Stream at the outlet of Garland Pond is more extreme. It is too warm by day and it does not cool off enough at night to support juvenile salmon. However, the ASC site just downstream at the bridge on the Fernald Road (the Bacon Mills site) is substantially cooler and does support salmon. Garland Pond is a shallow reservoir and is 4 miles (6.4 km) away from Bacon Mills. The well-shaded stream channel allows the stream to radiate excess heat. In addition, springs below Garland Pond and at the Bacon Mills site contribute to the improvements in water temperature. This site is known to support spawning adult salmon and is a good rearing area for parr. Allen Stream is also relatively cool while the French Stream site is marginal. Pierre Paul Brook is the coolest of all.

A different summary of the same temperature records is presented in Table 8. The same critical thresholds mentioned above are used but heat exposure is expressed in days. Crooked Brook got very warm, with 24 days where the daily maximum was above 24°C, and 4 days that exceeded 27° C, generally for a few hours at a time. These conditions are stressful but are not fatal for salmon. However, since there were only 2 days where the daily minimum did not drop below 22.5° C, fish can partially recover most nights. Sometimes these warm sites with much cooler nights are still very productive for juvenile salmon, apparently because the night time period offers sufficient recovery time for the fish (Richard Dill, ASC, personal communication). The Garland Pond outlet is clearly too warm for juvenile salmon, experiencing 41 days where the daily maximum exceeded the 24° C threshold. Eleven of these days were consecutive. An additional 3 days had daily maxima above the incipient lethal temperature of 27°C. However, the Bacon Mills site, Allen Stream and the Pierre Paul sites are suitable for salmon. Crooked Brook and French Stream are marginal, but probably could support salmon during cooler summers or in more shaded sites. The combination of abundant deeper, slow moving water

that favors exotic predators such as smallmouth bass may make French Stream less suitable for salmon stocking than temperature alone might indicate.

## Conclusions

The Kenduskeag Stream watershed is the most intensively farmed watershed in Penobscot County. According to the Penobscot County SWCD, there are 114 farms in the Kenduskeag watershed, including 27 dairy farms, 20 beef farms, 23 farms with goats or sheep, 15 potato farms, 26 market garden/dry bean operations and 5 orchards. Naturally, this amount of intensive agriculture has the potential to impact surface water quality. A report by the PCSWCD lists the principal water quality problems in Kenduskeag Stream as erosion and sedimentation, with considerable turbidity during storm events, low dissolved oxygen concentration (as low as 10% saturation in the lower river), high coliform bacteria (as high as 33,000 colonies per 100 ml), excessive nutrients and fish habitat degradation (PCSWCD, 1988). However, in the past 10 years there has been considerable improvement in farming practices.

Our study demonstrates that the upper tributaries and the upper part of Kenduskeag Stream are not grossly polluted streams. Except for some bacteria enrichment, the upper Kenduskeag watershed appears to meet Class A water standards. The river has unusual water chemistry, at least in comparison to other Maine surface waters. The pH is alkaline and the Kenduskeag is among the top 3% of the most alkaline water bodies where pH has been measured in Maine. This is a natural result of the carbonate rich bedrock in the watershed and may be supplemented by agricultural lime applications. The calcium levels are among the highest in the state. Nutrient levels appear to be enriched above background conditions, but are also at levels that can sustain a healthy and productive stream ecosystem. Sources of nitrogen in this region include abundant agriculture, atmospheric deposition, and septic systems. Some NPS pollution is present in the form of seasonal turbidity, enriched bacteria levels, and some elevated nutrient concentrations (especially in Kenduskeag Stream). However, small streams (defined as a width 10 m or less) are known to be important sinks for both ammonia and nitrate (Peterson et al, 2001). Thus, biological uptake and denitrification within our streams might be important mitigating processes. The relationships between stream flow and nitrate/TP concentrations are poor, but there might be a weak relationship in the mainstem of Kenduskeag

Stream with TP and flow. Seasonal changes in land use may be a factor in nutrient export, but we have not finished our land use analysis. Winter salt sand applications to local roads represent a non-point source (NPS) input of both salt and turbidity. Salt sand could be an important stress for fish and it contributes to loss of habitat due to embeddedness. Gravel roads and fallow fields may also contribute to turbidity and sediment loads.

Currently the upper Kenduskeag Stream and its uppermost tributaries appear to be meeting or surpassing state water quality standards. These streams are supporting Atlantic salmon, brook trout, many other fish and a rich assemblage of invertebrates. Dissolved oxygen levels currently meet water quality classification standards for the state. Suitable thermal regimes that are suitable for salmon were found in several locations, although some other sites are clearly too warm. People do use the river for recreation, although bacteria levels suggest that people should be cautious about contact with the water. This is especially true of high flow periods. There is no evidence at this time that the bacteria are of human origin, and in fact farm livestock are a more likely source. For instance, there are still some farms where pastures allow direct access of stock to stream banks (such as our site on Crooked Brook).

Some refinements for next year might include better control of the aluminum speciation samples, adding ammonia to the lab analysis, more bacteria studies, and looking at some sites that are located further downstream. We also need more turbidity/TSS measurements and better discharge data. Land uses, and especially seasonal cycles in human activities, need to be included in the analysis. Naturally, changes in our program will be finalized with input from our partner agencies. Some potential future restoration efforts might be to find ways to exclude farm stock from streams and banks, and finding ways to improve thermal regimes. The latter might involve improving shade and soil cover, improving flow or depth characteristics, and protecting springs. This too will require a lot of planning as well as coordination with the Soil and Water District and local landowners.

## **References Cited**

Bennett, EM, SR Carpenter and NF Caraco, 2001. Human impact on erodable phosphorus and eutrophication: a global perspective. *BioScience* 51 (3): 227-234.

Danie, DS, JG Trial, JG Stanley, L Shanks and N Benson, 1984. Species Profiles: Life histories and environmental requirements of coastal fish and invertebrates (North Atlantic), Atlantic salmon. US Fish and Wildlife Service, publ. no. FWS/OBS-82/11.22 (available on-line at <http://www.nwrc.usgs.gov/publications/specindex.htm>)

DEP, 2001. Surface Water Ambient Toxics Monitoring Program (SWAT), 2001 Ambient Biological Monitoring, available on-line at <http://www.state.me.us/dep/blwq/docmonitoring/swat/>

Elliott, JM, 1991. Tolerances and resistance to thermal stress in juvenile Atlantic salmon, *Salmo salar*. *Freshwater Biol.* 25: 61-70.

Forseth, T, MA Hurley, AJ Jensen and JM Elliott, 2001. Functional models for growth and food consumption of Atlantic salmon parr, *Salmo salar*, from a Norwegian river. *Freshwater Biol.* 46: 173-186.

Garside, ET, 1973. Ultimate upper lethal temperature of Atlantic salmon, *Salmo salar*. *Can J Zool.* 51: 898-900.

Mason, CF, SA Norton, IJ Fernandez and LE Katz, 1999. Deconstruction of the chemical effects of road salt on stream water chemistry. *J Environ. Quality* 28 (1): 82-91.

Murdock, T, M Cheo and K O'Laughlin, 1999. The Adopt-a-Stream Foundation Streamkeeper's Field Guide, Watershed Inventory and Stream Monitoring Methods. Published by the Adopt-a-Stream Foundation, Everett, Washington.

NADP website <http://nadp.sws.uiuc.edu/sites/>

NOAA website with local (Bangor) daily weather summaries  
<http://www.erh.noaa.gov/box/climate/daily.html>

Olson, SA and DJ Cowing, 1990-1991. National water quality summary: stream water quality: Maine. USGS Water Supply Paper 2400.

PCSWCD and SCS, 1988. Watershed plan – environmental assessment, Kenduskeag Stream watershed, Penobscot County, Maine. Penobscot County Soil and Water Conservation District and Soil Conservation Service (now known as the Natural Resources Conservation Service), USDA Building, Bangor Maine.

PEARL. Public Educational Access to Environmental Information on Lakes. Has the most recent VLMP annual report and summaries of information on Maine lakes on-line at <http://pearl.maine.edu/>

Penobscot County Soil and Water Conservation District website <http://www.penobscotswcd.org>

Peterson, BJ, WM Wollheim, PJ Mulholland, JR Webster, JL Meyer, JL Tank, E Marti, WB Bowden, HM Valett, AE Hershey, WH McDowell, WK Dodds, SK Hamilton, S Gregory and DD Morrall, 2001. Control of nitrogen export from watersheds by headwater streams. Science 292: 86-90.

SHARE website <http://www.salmonhabitat.org>

Smith, RA, RB Alexander and GE Schwarz, 2003. Natural background concentrations of nutrients in streams and rivers of the conterminous United States. Environ Sci and Technol 37 (14): 3039-3047.

VLMP, 2003. Maine Volunteer Lake Monitoring Program, Annual Report. Available on-line at [www.mainevolunteerlakemonitors.org](http://www.mainevolunteerlakemonitors.org)

Whiting, MC, 2003. Maine salmon rivers water quality monitoring project, progress report for 2003 field season. Maine Dept of Environmental Protection, Bangor Regional Office.